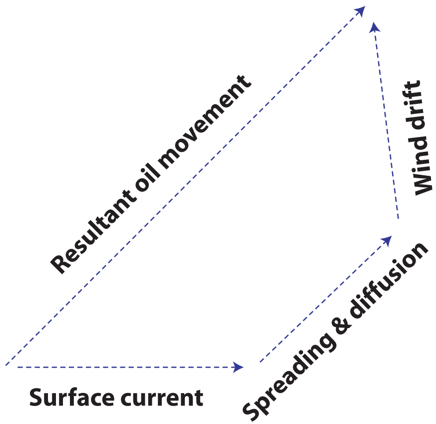
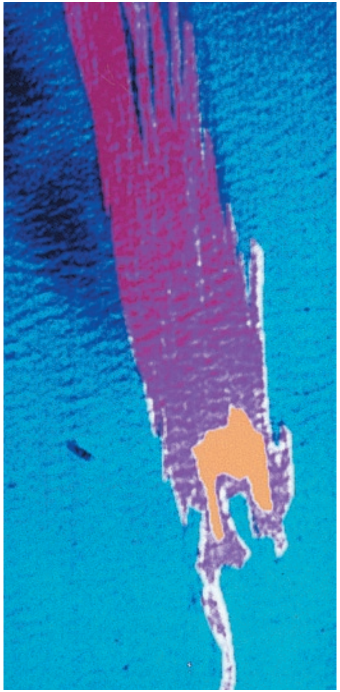


Oil Transport

Two major processes transport oil spilled on water: spreading and advection. For small spills (<100 barrels), the spreading process is complete within the first hour of the release.

Winds, currents, and large-scale turbulence (mixing) are advection mechanisms that can transport oil great distances.

In general, the oil movement can be estimated as the vector sum of the wind drift (using 3% of the wind speed), the surface current, and spreading and larger-scale turbulence (diffusion).



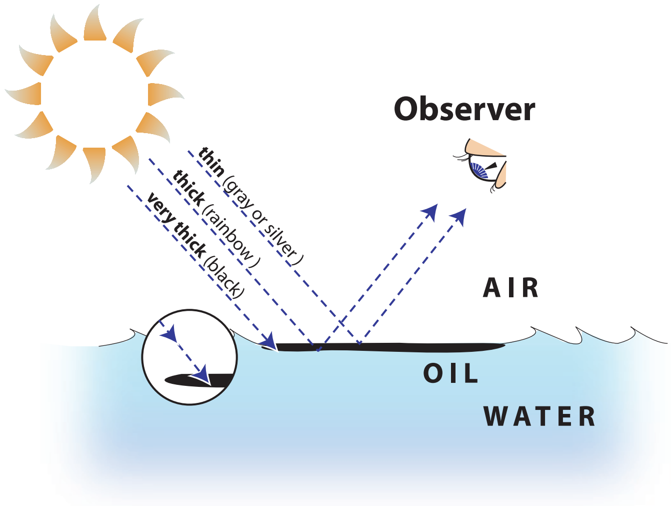
Color-enhanced image of a test spill (<50 barrels).

Oil Spreading

The spreading process occurs quickly and, for most spills, mostly within the first hour. In the open ocean, winds, currents, and turbulence will quickly move the oil.

Spreading will occur quicker for lighter and for less viscous oils in warm water temperatures and for warm oils.

The slick does not spread uniformly but will often have a thick part surrounded by a larger, but thinner sheen. The figure shows a color-enhanced image of an experimental spill. The orange portion is the thick part of the slick and the pink area, sheen. Note that about 90% of the oil is found in 10% of the slick area (the orange portion of the figure).



Very thin films: no phase shift or reflection and all frequencies reflected back (gray or silver)

Intermediate films: phase shift depends on wave length or color and distance traveled through the oil (rainbow)

Thick films: light is absorbed (brown or black)

Trajectory analysis does not typically provide good information on oil thickness.

Oil Thickness

Oil slicks form very thin films on the open water and, depending on the product, the thickness can range from a tenth of a micron to hundreds of microns. Since 1929, oil spill researchers have studied the relationship between oil thickness and the color of the film.

When direct light from the sun contacts a very thin oil film (<0.1 micron; µm), much of the light is reflected back to the observer (see diagram) as gray or silver sheen.

If the film is thicker (perhaps 0.1 to 3 µm), the light passes through the film and is reflected off the oil-water interface and back to the viewer. The observer will then see a film that can range from rainbow to darker-colored sheens.

For very thick films (> 3 µm), the light is absorbed and the slick will appear dark- colored (i.e., black or brown) to the observer. However, the viewer can no longer determine film thickness based on color. If the slick is dark-colored, the observer cannot tell whether the film is 3 µm or 100 µm thick.

Because sun angle, glare, sea state, view angle, and viewing through plexiglass windows can affect the appearance of the slick, estimating film thickness based on color is unreliable. Calculating oil volume also requires estimating the percent oil coverage, a very difficult task.

Wind affects on oil trajectory

	Wind Speed		
	LOW <5 knots		HIGH>25 knots
evaporation		increases	
dispersion		increases	
patchiness		increases	
convergences	natural	Langmuir	
observability	good		poor

Winds

Winds affect the trajectory in three major ways:

1) oil weathering
2) surface effects on the water
3) direct transport

Estimating Wind Speed From Helicopter

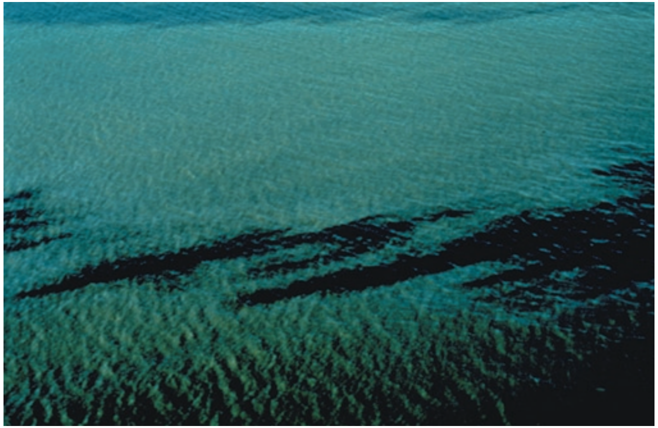
Wind speed	Waves
0 to 5 knots	Round or sinusoidal shape
5 to 10 knots	Trochoid shape (peaks are pointed)
10 knots	Breaking waves
15 knots	Tops are coming off the waves
20 knots	Streaks of foam trailing behind waves
>20 knots	Difficult to observe surface oil

Wind Speed Scale

The Beaufort Wind Scale is named after Admiral Sir Francis Beaufort, who developed the scale in 1805 to estimate wind speed from observing the sea state. The table at left provides an alternative approach to estimating wind speed, particularly useful if you are observing from an aircraft. The following table shows the Beaufort Wind Scale for wind speed and the corresponding sea characteristics.

Wind Scales and Sea Descriptions (From Willard Bascom, *Waves and Beaches*, 1980)

Beaufort Scale	Seaman's description of wind knots	Velocity (knots)	Estimating wind velocities on sea	International scale sea description and wave heights
0	Calm	<1	Sea like a mirror	Calm, glassy 0 foot
1	Light air	1-3	Ripples, no foam crests	
2	Light breeze	4-6	Small wavelets, crests have glassy appearance and do not break	Rippled, 0-1 foot
3	Gentle breeze	7-10	Large wavelets, crests begin to break. Scattered whitecaps.	Smooth, 1-2 feet
4	Moderate breeze	11-16	Small waves becoming longer. Frequent whitecaps.	Slight, 2-4 feet
5	Fresh breeze	17-21	Moderate waves taking a more pronounced long form; mainly whitecaps, some spray.	Moderate, 4-8 feet
6	Strong breeze	22-27	Large waves begin to form extensive whitecaps everywhere, some spray.	Rough, 8-13 feet
7	High wind (moderate gale)	28-33	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	Very rough, 13-20 feet
8	Gale (fresh gale)	34-40	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.	Very rough 13-20 feet,



Windrows

Wind Drift

Observations of actual oil spills and controlled experiments indicate that the wind drift can range from 1 to 6% of the wind speed (most modelers use an average of 3%). The lower windage value of 1% reported may be due to some of the oil droplets being submerged by waves. Langmuir circulation can also result in wind drift variability. The oil within the windrows may move up to 5.5% of the wind speed. This hypothesis would account for the higher windage value of 6% reported at spills.

While oceanographic theory predicts an angle between the surface current and the wind speed, observations of oil slick trajectories suggest that the actual angle is less than 10°. Wind direction predictions are typically not this accurate and few modelers include a rotation angle in their calculations.

Most modelers use wind speeds measured at 10 meters above the water surface. Observations at other heights are adjusted by standard techniques to the standard 10-m height.

It should be noted that wind direction is commonly reported as the direction *from* which the wind is blowing and the surface current is reported as the direction *toward* which the water flows. This means that a north wind and a southerly current are moving in the same direction.

Drifters

Currents

The surface current is a mechanism for transporting oil. Currents are an important factor in determining the length and time scale of a spill.

- Ocean circulation can transport oil for thousands of miles in months to years
- Ocean coastal flow can transport oil for hundreds of miles in weeks
- Estuarine circulation can transport oil tens of miles in days
- Rivers can transport oil tens of miles in hours to days